Non-Linear Effects during Electrolytic Deposition of Copper

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Abstract

Mechanisms of non-uniform copper film formation during electrolytic deposition are investigated. A non-linear theoretical model based on Butler-Volmer kinetics of deposition is proposed and compared with experimental data. We compare our non-linear approach to the traditional linearized approach used to describe current density across the wafer (Takahashi). In the traditional linear approach, non-linear effects associated with the electrode kinetics are disregarded. The linearized model provides a reasonable approximation to a Butler-Volmer kinetics based model at very low applied currents (Figure 1). However at higher applied currents commonly used in real plating processes, the predictions based on the non-linear and linear approaches differ drastically. When using the linear model the differences leads to erroneous predictions of the plating profiles for both 200 and 300 mm wafers (Figures 2, 3).

The analysis also suggests that different mechanisms might control the uniformity of the film deposition at different stages of the plating process. We have shown that in most practical cases the high resistivity of the seed/barrier layers provides a relatively minor contribution to the overall film non-uniformity as compared to the non-linear effects caused by the Butler-Volmer kinetics (Figure 4). We have also shown that mass transfer controls the uniformity of the film at later stages of the deposition process. Plating in this regime leads to the formation of films that are flatter than films deposited in the kinetics controlled mode. Experimental data obtained with 200 mm blanket copper wafers confirm these findings.

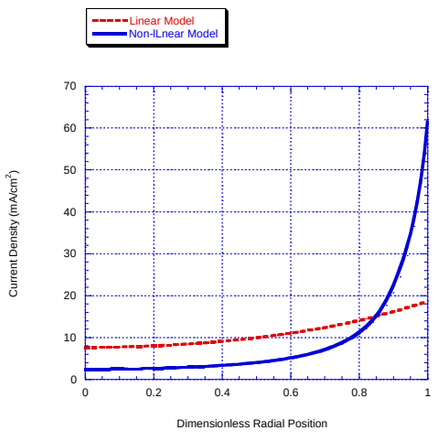

Figure 2. Current distribution for 200 mm wafers at 4 A current and 0.9 mA/cm^2 exchange current density. Linear model – dotted line, non-linear model – solid line

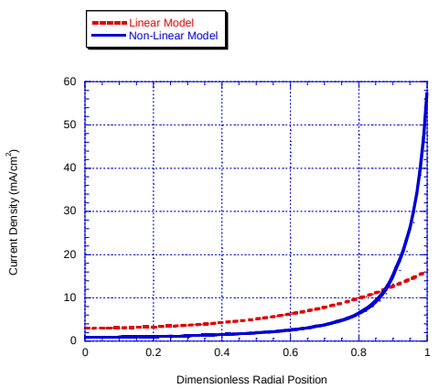

Figure 3. Current distribution for 300 mm wafers at 6 A current and 0.9 mA/cm^2 exchange current density. Linear model – dotted line, non-linear model – solid line

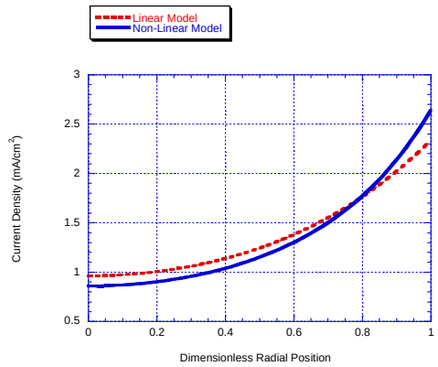

Figure 1. Current distribution for 200 mm wafers at 0.5 A current and 0.9 mA/cm^2 exchange current density. Linear model – dotted line, non-linear model – solid line

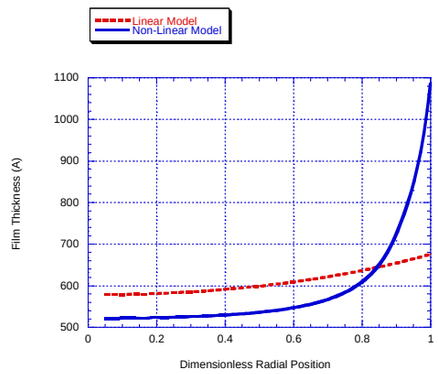

Figure 4. Copper thickness for 200 mm wafers at 5 A current and 0.9 mA/cm^2 exchange current density. Linear model – dotted line, non-linear model – solid line

References:

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